

Introduced flow variability and its propagation downstream of hydropower stations in Sweden



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MOTIVATION

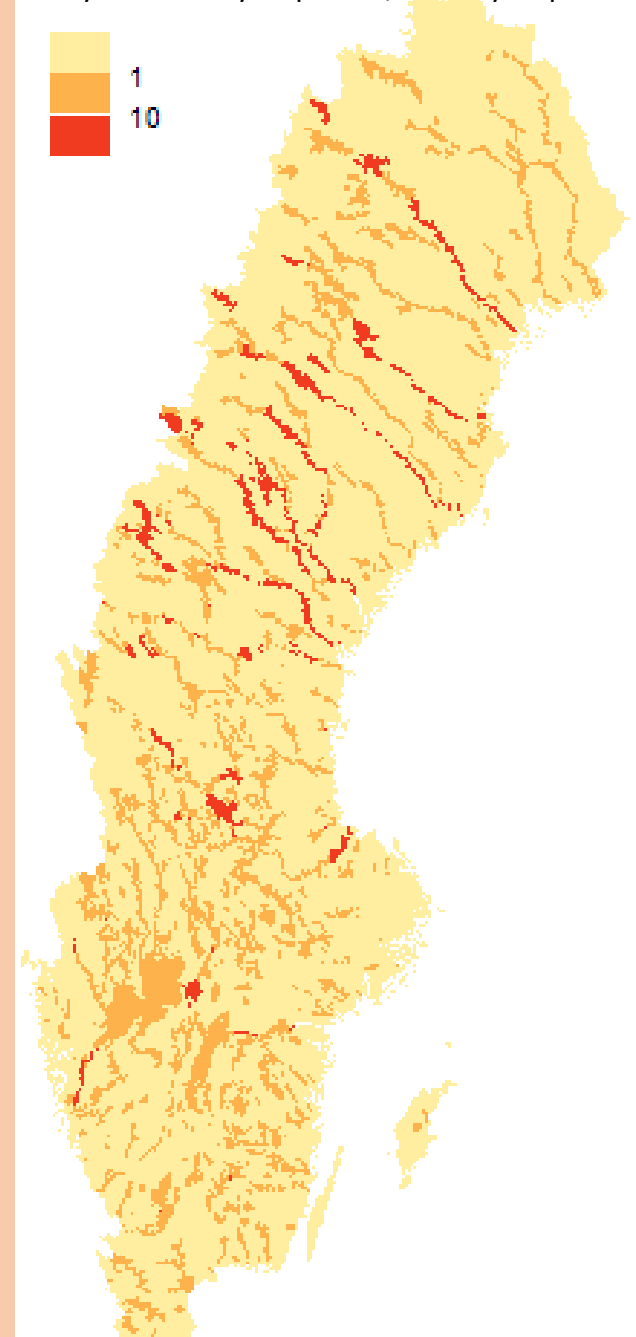
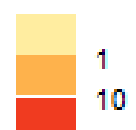
Ecological impacts must be assessed in the ongoing process of renewing all Swedish hydropower permits. **Habitats can be lost due to frequent flow fluctuations¹** from hydropower regulations, related to variable electricity demand and renewable energy production. **Knowledge on damping of these fluctuations is essential to assess downstream ecological status.**

METHODS

We performed flow simulations with the HYdrological Predictions for the Environment (HYPE) rainfall-runoff model², using a daily time step. Flow variability from **short-term regulations was introduced by station updates**. A second model simulates flow without regulations. River **attenuation** is modeled by a combined translation and **level-pool** method. The Fast Fourier Transform was used to obtain amplitudes of modes with different periods. A solution to the diffusion-wave equation for sinusoidal input was used to further analyze the attenuation process.

IMPACT OF HYDROPOWER ON FLOW VARIABILITY

7-day mode: A hydropower / A no hydropower



Regulations on the **weekly** time scale often have the largest amplitude out of modes 2-30 days.

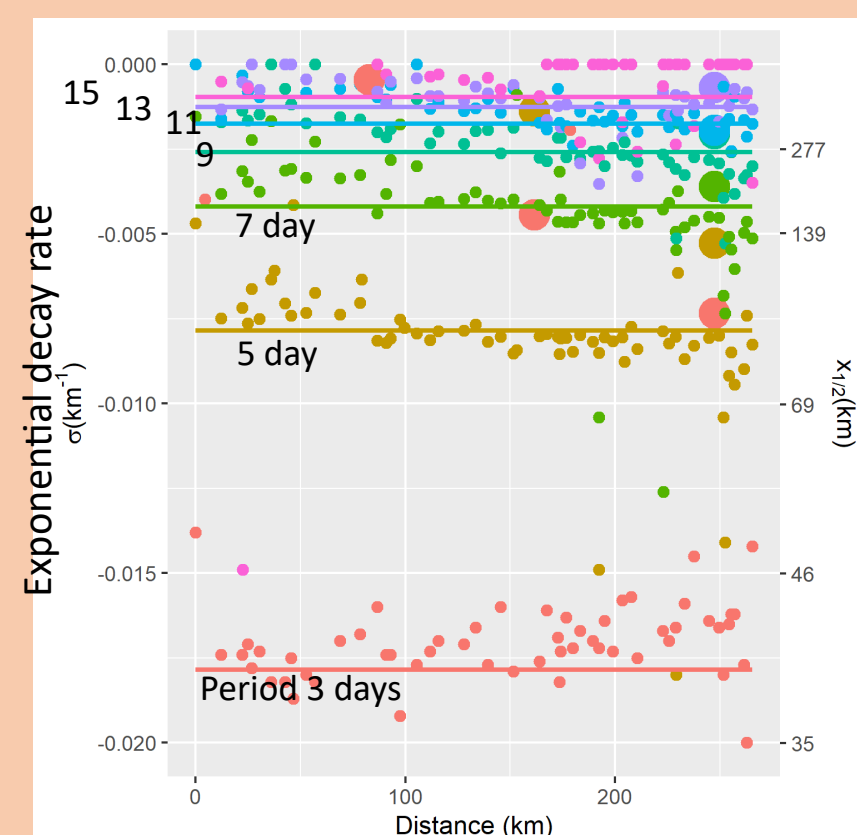
The figure shows that the amplitude (m^3/s) of the 7-day mode is **often increased by more than a factor 10 due to hydropower** in the large regulated rivers. In unregulated rivers some change also exists, due to station-update which is only performed in simulations with hydropower.

“River stretches between hydropower dams in Sweden are often quite level and effective at reducing introduced variability.”

However, closely spaced regulation dams may cause negligible attenuation overall.”

VERIFIED SIMULATED ATTENUATION IS DUE TO FRICTION

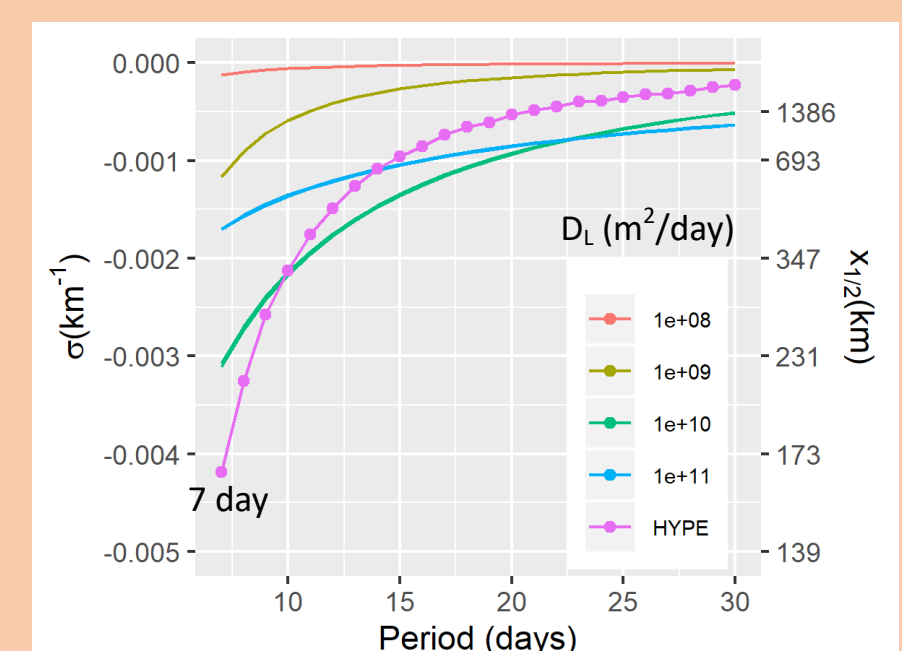
The simulated attenuation was verified against observed attenuation for modes larger than 5 days, as shown for river Västerdalälven by small dots (simulation) and the last large circle (observation largely unaffected by regulation).



The 3- and 5-day modes were too much attenuated using the daily time step. The 15-day mode was growing between the last two observations due to a tributary impacting this mode. **The weekly mode requires 150 km undisturbed river to be reduced by a factor of two. However, dams are often spaced on the order of only tens of kilometers.**

Lines showing attenuation with only translation and level-pool mixing (no precipitation, runoff etc), are close to the verified simulation results, demonstrating that **river processes dominate attenuation of perturbations that are inserted instream** (i.e. from hydropower).

A **large dispersion coefficient** on the order $10^{10} \text{ m}^2/\text{day}$ ($10^5 \text{ m}^2/\text{s}$) consistent with **small slopes between dams** must be used to obtain diffusion-wave attenuation close to verified HYPE results, i.e. with enough attenuation of the weekly mode caused by **friction**.



REFERENCES

1 L.M. Tallaksen & H.A.J. van Lanen (2004) Hydrological drought. Processes and estimation methods for streamflow and groundwater. Elsevier

2 Lindström, G., Pers, C., Rosberg, J., Strömqvist, J. & Arheimer, B. (2010) Development and testing of the HYPE (Hydrological Predictions for the Environment) water quality model for different spatial scales. Hydrology Research 41.3-4, 295-319.

